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A. Ye. Mikirov

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THE ESTIMATION OF OZONE CONCENTRATION AT THE HEIGHTS OF 44-102 KM DURING NIGHT LAUNCHINGS OF GEOPHYSICAL ROCKETS

A. Ye. Mikirov

ABSTRACT 21688

High-altitude measurements of atmospheric brightness /1120* as a function of altitude under lunar illumination are used for determining ozone concentration at altitudes between 44 and 102 km. The experimental conditions and formulas used in the calculations are given. The experimentally determined value of $\sim 0.4 \cdot 10^{-19}$ O_3 molecules/cm^3 above 44 km agrees satisfactorily with the data in the literature.

Author

FIR instruments (ref. 1) mounted in the oriented spherical container of an automatic high-altitude geophysical station (ref. 2) were used for studying the brightness of the atmosphere at altitudes of 44-102 km during night launchings of geophysical rockets. The purpose of the experiments was to determine the change in brightness with altitude when the atmosphere is illuminated by moonlight. The rocket was launched at 4 h 03 m LT. A diagram showing the location of the instruments in the container and the orientation of the container in space for this launching is given in figure 1. The optical axis of FIR pickup No. 4 made an angle of 10° with the equatorial plane of the container. The zenith angle of the moon during the experiment was $76^\circ 30'$. Thus the No. 4 pickup was directed at the moon in this experiment.

*Numbers given in margin indicate pagination in original foreign text.

Measurements of the intensity of lunar radiation were used as a basis for determining the ozone concentration at altitudes of 44-102 km, i. e. at altitudes above the maximum concentration under nocturnal conditions.

A study of ozone by direct methods is of considerable interest, particularly at altitudes above the maximum concentration. Methods for studying atmospheric ozone are rather well developed at the present time (refs. 3-5). The equation of atmospheric absorption is the basis for ozone determinations of this type. The measured radiation intensity of an extraterrestrial /1121 light source with a known radiation during passage through the earth's atmosphere is

$$I_\lambda = I_{0\lambda} \exp\left(-\int_n^\infty \alpha_\lambda E_z dl - \beta_\lambda m_1 - \eta_\lambda m_2 \right),$$

where $I_{0\lambda}$ is the intensity of monochromatic radiation from the extraterrestrial source at the boundary of the atmosphere; I_λ is the measured spectral intensity of the same source; α_λ is the spectral coefficient of absorption for ozone radiation; E_z is the concentration of ozone at altitude z; l is the path of a

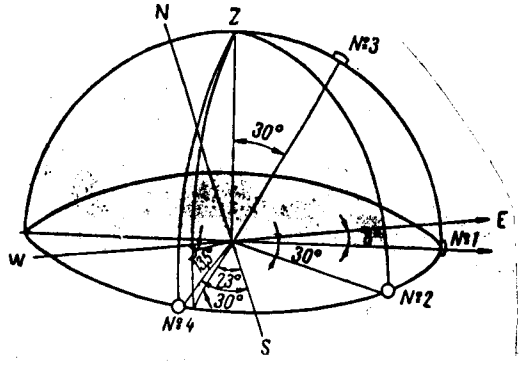

Fig. 1

beam to the instrument located at altitude h; β_λ is the coefficient of scattering for an absolutely pure atmosphere; m_1 is the mass of the atmosphere at altitude h, given by the expression

H_0 is the altitude of the uniform atmosphere; ρ_0 and ρ_z are atmospheric densities at the surface of the earth and at altitude z; η_λ is the aerosolic coefficient of attenuation; m_2 is the aerosolic "atmospheric mass".

Let us use two sections of the spectrum with effective wavelengths λ_1 and λ_2, choosing these wavelengths in such a way that $\alpha_{\lambda_1} \neq 0$ and $\alpha_{\lambda_2} = 0$. This condition can obviously be fulfilled by simply taking measurements in the spectral region from $\lambda_1 = 5850$ Å to $\lambda_2 = 4200$ Å. Then

$$I_{\lambda_1} = I_{0\lambda_1} \exp\left(-\int_n^\infty \alpha_\lambda E_z - \rho_1 m_1 - \eta_1 m_2\right),$$
$$I_{\lambda_2} = I_{0\lambda_2} \exp(-\beta_2 m_1 - \eta_2 m_2).$$

Thus we derive equations for finding E_z with terms containing β_1, β_2, η_1 and η_2.

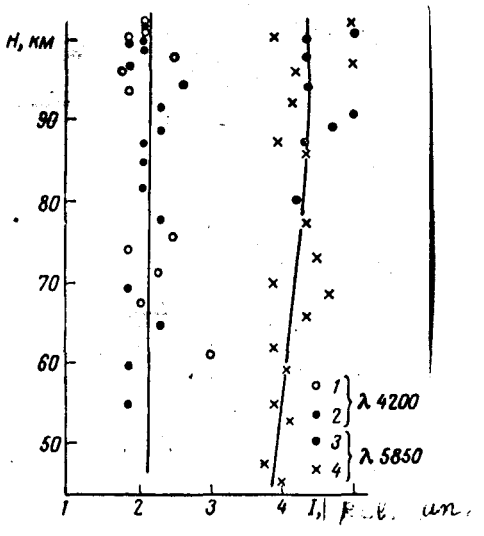

Fig. 2

Let us consider the values of coefficients β and η. For altitudes of $\sim$40 km, the coefficient $\beta_m \ll 1$, in the 4000-6000 Å spectral region, having a value of $\sim 10^{-4}$. As altitude increases, β_m decreases in proportion to the re-

duction in atmospheric density.

It is known (ref. 1) that the optical aerosolic thickness η_m at altitudes of $\sim$70 km is approximately equal to the optical thickness of the absolutely pure atmosphere β_m. At altitudes lower than 70 km, the aerosolic optical thickness is less than the optical thickness of the absolutely pure atmosphere. This is apparently caused to a considerable extent by an increase in the Rayleigh scattering coefficient rather than by any reduction in the aerosol concentration at these altitudes, i. e. the aerosolic optical thickness at altitudes of $\sim$40 km will not exceed 10^{-4}. As a consequence of the smallness of optical thickness $\beta_1 m_1$, $\beta_2 m_1$, $\eta_1 m_2$ and $\eta_2 m_2$, the fundamental equation which determines the radiation absorption will be

$$I_{\lambda_1} = I_{0\lambda_1}(1-\beta_1 m_1)(1-\eta_1 m_2)\exp\left(-\int_n^\infty \alpha_{\lambda_1} E_z dl\right), \qquad I_{\lambda_2} = I_{0\lambda_2}(1-\beta_2 m_1)(1-\eta_2 m_2).$$

Since the scattering coefficient for aerosols is rather weakly dependent on wavelength, we may obviously assume that $\eta_1 = \eta_2$. As for coefficients β_1 and β_2, in the case of our choice of wavelengths λ_1 and λ_2, $\beta_2 = 3.7\beta_1$. Then, taking the ratio of the measured values for the two wavelengths, we get

/1122

$$\frac{I_{\lambda_1}}{I_{\lambda_2}} = \frac{I_{0\lambda_1}}{I_{0\lambda_2}}(1-2.7\beta_1)\exp\left(-\int_n^\infty \alpha_{\lambda_1} E_z dl\right)$$

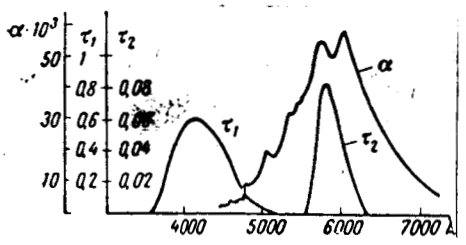

Fig. 3

It is necessary for a solution of the problem to know $I_{0\lambda_1}/I_{0\lambda_2}$. These values may be determined from the coefficients for lunar reflection (ref. 8)

and intensity of solar radiation (ref. 9). We determined $I_{\lambda_1}/I_{\lambda_2}$ on this basis and got a value of 1.9. This same ratio may be determined from experimental data if the measurements are made at sufficiently high altitudes

In this experiment, the attenuation of lunar radiation intensity was measured at 102 km. Figure 2 gives the intensities measured in the two sections of the spectrum (*1*, *3*--motion upward; *2*, *4*--motion downward). There is a great degree of scatter in the experimental points.

This is explained by the fact that the image of the moon on the cathode of the photomultiplier was in the form of a point. Since the spatial orientation of the automatic high-altitude geophysical station is not strictly constant ($\pm 0.5^{\circ}$ at best) and the sensitivity of the photomultiplier cathode is not uniform, the scatter in points is completely understandable, and no more exact experimental data could have been expected.

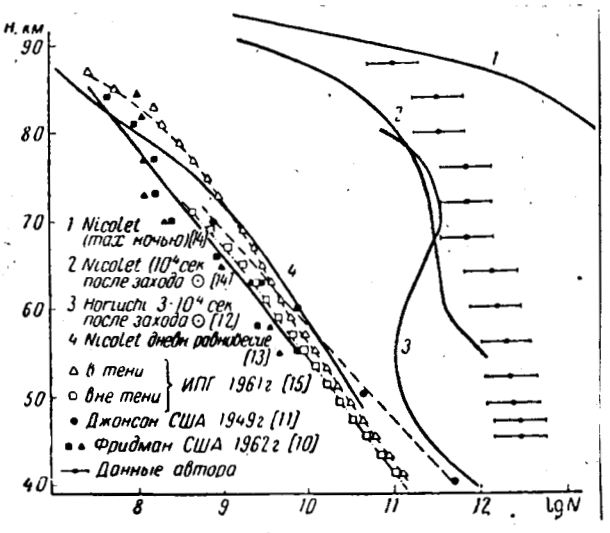

Fig. 4

Legend: 1--Nicolet (night maximum) (ref. 14); 2--Nicolet (10^4 sec after sunset) (ref. 14); 3--Horiuchu ($3 \cdot 10^4$ sec after sunset) (ref. 12); 4--Nicolet (daytime equilibrium) (ref. 13); ▲ (in the umbra) and □ (outside the umbra)--Inst. of Appl. Geophys., 1961 (ref. 15); ● --Johnson, U.S.A., 1949 (ref. 11); ▮▲--Fried-

man, U. S. A., 1962 (ref. 10); ⟷--author's data.

The spectral characteristics of the light filters used are given in figure 3. At 90 km and above, the experimental data for λ_1 do not change with altitude and conform rather well with the numerical values of $I_{0\lambda_1}/I_{0\lambda_2}$.

The measured values of lunar radiation intensity for λ_2 show a constant change with altitude. This confirms our hypothesis on the smallness of optical thicknesses βm_1 and ηm_2. Then for determining the ozone concentration, we have finally

$$I_{\lambda_1} = I_{0\lambda_1} \exp\left(- \int_n^\infty \alpha_{\lambda_1} E_z dl \right).$$

The concentration of ozone with altitude was calculated from the experimental data. The Wigner coefficient of absorption was used in the calculations. The numerical values of the ozone concentration are given in figure 4. The data of other authors (refs. 10-15) are also given for comparison. The resultant values for the concentration are somewhat higher than the theoretically calculated data based on photometric equilibrium conditions. As to the total ozone concentration at altitudes of $\sim$44 km and higher, our evaluation shows that it is $\sim 0.4 \cdot 10^{-19}$ molecules per cm^2 which agrees with the data in literature.

However, it should be pointed out that our data are not highly accurate. Consideration of all factors which contribute to the error in the final result indicates that the error in the resultant values of ozone concentration is ±100-120%.

In conclusion, I consider it my duty to thank S. M. Poloskov, A. M. Kasatkin, S. V. Repolovskiy (deceased), A. Ye. Khaletskiy and A. A. L'vova for assistance with the work and useful consultation.

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